UNITED STATES PATENT APPLICATION

of

Sharon A. Elsworth,
Marvin I. Fredberg,
William H. Fossey, Jr.,
Staurt Press,
&
Thad Fredrickson

for

High Strength, Long Durability Structural Fabric/Seam System

DALY, CROWLEY & MOFFORD, LLP
275 Turnpike Street, Suite 101
Canton, MA 02021-2310
Telephone (781) 401-9988
Facsimile (781) 401-9966

Express Mail Label No.: ER477500692US

TITLE

High Strength, Long Durability Structural Fabric/Seam System

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of provisional application serial number 60/445,940 filed February 7, 2003, the disclosure of which is hereby incorporated by reference.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

This work was sponsored under Department of Defense Contract No. HQ006-01-C-001. The government has certain rights in this invention.

FIELD OF THE INVENTION

The present invention relates generally to treated woven, knitted or unidirectional fabric, and more particularly to a treated woven, knitted or unidirectional fabric which is used to provide structures that can withstand high level working loads and extreme environmental conditions.

BACKGROUND OF THE INVENTION

Woven or knitted fabrics coated with a resin such as Poly-Vinyl Chloride (PVC), polytetrafluorethylene (PTFE), urethane or other suitable resin have been used to provide structures. The fibers or fiber bundles of the woven fabric are coated with a resin, thereby forming a matrix surrounding the fibers. The matrix material is typically the medium, by which seams in the construction, can transfer load across the joints in the fabric. One example of such a structure is a radome, which is a dome shaped protective housing used to cover a radar antenna. A radome may be subject to a severe set of conditions such as supporting heavy loads for extended periods of time at extreme temperatures and humidity.

Traditional fabric structures apply resin-based coatings to the fabric substrate via 'knife-over-roll' or film lamination techniques. In order to take structural advantage of a fiber structure, applied loads should be able to transfer from one fiber bundle to another and the full load capability of the fabric should be able to be transferred across joints in the fabric. The resin system applied to the fabric assists with load transfer. However, the effectivity of this load transferring ability is directly related to the interface between the fiber and the resin. This interface is dependent both on the volume of surface contacted, the linkage between the fiber surface and the resin, and the resin properties. When a fabric is coated with resin, the coating is only in contact with the exposed outer surface of the fiber bundles and, effectively, the fiber/resin product (also referred to as the fabric product) is full of voids or air pockets within the fiber bundles. When an applied load encounters a void, the load cannot be transferred or carried from fiber filament to filament. The propagation of the load effectively stops and a stress concentration develops that eventually exceeds the fabric load resistance, resulting in a failure of the fabric product. This effect is most pronounced at the fabric seam locations where the fiber bundles are not continuous across the joint.

A drawback associated with these coated woven fabrics and seams is that when they are utilized to provide a structure such as a radome, they typically do not withstand the long duration, high level working loads and extreme environmental conditions.

One attempt to resolve the above-mentioned drawback was to increase the base fabric load carrying capability, load transfer capability and fiber bundle load sharing capability by modifying existing fabric weave designs. These attempts did not produce a fabric/seam system product, which could withstand the working loads and environmental conditions mentioned above. Another attempt to overcome the above mentioned drawback involved development of new fabric/fiber technology. Although this attempt utilized innovative fiber and fabric designs, this attempt relied on traditional fabric coating technology that failed to achieve the required combination of properties between the fiber system and the resin matrix, resulting in premature seam failure. The net result of both attempts was unacceptable operation in the area of seam performance of the

structure.

SUMMARY OF THE INVENTION

A high strength, high modulus structural fabric product and the method of manufacturing the product are presented. The incorporation of a fiber/fabric treatment coupled with a resin impregnation and coating process produces a composite material. This composite material comprises high strength and modulus fibers embedded in and coupled to a matrix such that the resin matrix material penetrates to the filament level of the fiber bundle. The resulting fabric product is useable in the formation of structures, which carry and distribute high-level loads across seams under extreme environmental conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a diagram of the fabric product; and

Figure 2 is a flow chart of the process utilized to produce the fabric product.

DETAILED DESCRIPTION OF THE INVENTION

The present invention comprises a high strength, high modulus structural fabric product and the method of manufacturing the product. Utilizing a fiber/fabric treatment and a resin impregnation and coating process a fabric product useable in air-supported structures, which is able to carry and distribute high level loads across seams under extreme environmental conditions and with high levels of survivability, is provided. The incorporation of a fiber/fabric treatment coupled with a resin impregnation and coating process produces a composite material. This composite material comprises high strength and modulus fibers embedded in and coupled to a matrix such that the resin matrix material penetrates to the filament level of the fiber bundle. In this form, both the fibers and the matrix retain their physical and chemical identities, and further produce a combination of properties that are not achieved with either constituent acting alone.

In general, the fibers of the fabric are the principal load carrying members. The fabric is combined with a surrounding resin matrix which keeps the fibers in a desired location and orientation. The surrounding matrix further acts as a load transfer medium between the fibers, provides a shear load transfer medium across seams and protects the fibers from damage due to environmental conditions such as temperature, humidity, and sunlight.

The present invention utilizes a resin application technology that effectively 'impregnates' a fabric substrate such that the resin surrounds fibers and fiber bundles and infiltrates the fiber bundles to the filament level. The result is a fabric structure that has the combined properties of the resin for load transfer capabilities and the fiber/fabric system to carry loads.

Referring to Figure 1, a sectional isometric view of a particular embodiment of a fabric product 1 incorporating the present invention is shown. The fabric product 1 includes resin impregnated fabric layer 60. The resin impregnated fabric layer includes a fabric made of fibers such as Vectran®, Kevlar® or other high performance fiber which has been impregnated with the resin. As discussed above, the resin surrounds and infiltrates the fiber bundles of the fabric to the filament level.

The resin impregnated layer 60 has a resin coating layer 50 disposed across a top surface and a resin coating layer 52 disposed across the bottom surface. The resin coating layers thus cover the top and bottom surfaces of the resin impregnated fabric layer. Also shown is a second resin impregnated layer 62, which also has a resin coating layer 54 disposed across a top surface and a resin coating layer 56 disposed across the bottom surface of the resin impregnated fabric layer 62. While fabric product 1 comprising two-layers of the resin layer-resin impregnated fabric layer-resin layer groups is shown it should be appreciated that a fabric product could be comprises of any number of resin impregnated fabric layers and resin layers.

The resulting fabric product 1 may contain one or more resin impregnated fabric layers, 60 and 62 which are formed using a two-part castable urethane or other suitable resin system capable of providing resin penetration to individual filaments of the fabric. As an example, traditional two part castable urethane systems use a resin to curative stoichiometry range of 85 to 110% theory. The curative stoichiometry refers to the ratio of chemical components and the ratio of reaction to each of the components. Typical stoichiometry are in the 95% range. A fabric product produced using a resin system 85 – 110% stoichiometry range did not achieve the desired performance.

Traditionally, stoichiometry range levels below 85% have not been used, with the belief that an unusable polymer would result. However, by using a 75% stoichiometry range level, the resulting composite (also referred to as an impregnation compound) yielded both high shear strength under high seam loads and uniform strength throughout the composite. This result is in direct contrast to prior experience and recommendations of resin manufacturers.

In a particular embodiment the impregnation compound includes three components: a urethane pre-polymer, a co-reactant curative, and a diluent, such as toluene. The impregnation compound in this embodiment is formulated as follows:

Polyurethane Specialties Pre-Polymer PCA 6-3	100.0 Parts by weight
Uniroyal Chemical Caytur 31 curative	26.1 Parts by weight

The mixture is then diluted to 75% total solids with toluene. The ratio of curative to pre-polymer is derived from the formula:

$$\frac{6.34x0.75x230}{42} = \text{parts by weight of curative per 100 parts of pre-polymer}$$

where 6.34 is the isocyanate content of the pre-polymer, 0.75 is the desired

stoichiometry, 230 is the equivalent weight of the curative, and 42 is the equivalent weight of the isocyanate.

As described above, traditional fabric structures apply resin based coatings to the fabric. When a fabric is coated with resin, the coating is only in contact with the outer filaments of the fiber bundles and, effectively, the fiber/resin system is full of voids or air pockets within the fiber bundles. When an applied load encounters a void, the load cannot be transferred or carried. The propagation of the load effectively stops and a stress concentration develops that eventually becomes greater than the fiber/fabric strength. These coating techniques do not drive the resin into the interstitial sites of the fabric nor into the individual fiber bundles or fiber filaments of the fabric.

A flow chart of the presently disclosed method for applying the impregnating compound into the fabric is depicted in Figure 2. The rectangular elements are herein denoted "processing blocks" and represent instructions or groups of instructions.

The method of producing the fabric product is described in conjunction with the flow chart of Figure 2. The method 100 begins at processing block 110 wherein the base fabric is scoured to remove any lubricants applied by the yarn manufacturer, or those lubricants applied by the weaver. These lubricants could interfere with the development of high integrity resin to the base fabric interface. After scouring, processing proceeds with processing block 120.

Processing block 120 recites treating the fabric with a polymeric isocyanate to enhance adhesion of the impregnation compound to the fabric. Processing block 130 is performed next wherein the impregnation of the base fabric is performed. The impregnation of the fabric involves the continuous submersion of the fabric in a tank containing the impregnation compound.

At processing block 140, after the fabric emerges from the tank, the fabric is

squeezed by a set of nip rolls to further drive the impregnation compound into the fabric fibers and to remove any excess impregnation compound.

The fabric is then fed into a drying oven, as shown in processing block 150. Preferably the drying oven is set at a temperature as required to remove diluents from the fabric-resin composite.

Processing block 170 is executed next wherein the resulting impregnated fabric is post cured at a temperature as required to cure the resin system. Following processing block 170 the fabric is ready for subsequent processing.

The resulting impregnated fabric is incorporated into the fabric product and is used to produce fabric structures. In the case of a radome incorporating the present invention, the radome fabric can withstand working loads as high as 880 pounds per inch width for 56 hours at a temperature of 35 degrees C in a humid environment. This invention allows the use of thermally welded seams to meet these demanding requirements. Seams made from this material are able to withstand in excess of 56 hours at 880 pounds per inch load, with high humidity, at 35^0C using an overlap seam construction. This seam performance has not been achieved in other flexible composite applications

A high strength, high modulus structural fabric product and the method of manufacturing the product have been described. The incorporation of a specific fiber/fabric treatment coupled with resin impregnation and coating processes produces a composite material. This composite material comprises high strength and modulus fibers embedded in and coupled to a matrix. The resulting fabric product is useable in the formation of seamed structures which carry and distribute high-level loads under extreme environmental conditions.

Having described preferred embodiments of the invention it will now become apparent to those of ordinary skill in the art that other embodiments incorporating these concepts may be used. Accordingly, it is submitted that that the invention should not be limited to the described embodiments but rather should be limited only by the spirit and scope of the appended claims. All publications and references cited herein are expressly incorporated herein by reference in their entirety.